Faculty of Manufacturing Engineering

EFFECT OF DRYING PROCESS TO THE DIMENSION OF MACHINED CORE

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EFFECT OF DRYING PROCESS TO THE DIMENSION OF MACHINED CORE

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A thesis submitted

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DECLARATION

I declare that this thesis entitled "Effect of Drying Process to The Dimension of Machined Core" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Manufacturing Engineering (Industrial Engineering).

Signature	: ....
Supervisor name	: ....
Date	: ....

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ABSTRACT

The continuous demands for low-weight structures ensure that honeycomb sandwich construction have many advantages. In aircraft industry, generally the honeycomb core can be divided into two types which are Nomex Honeycomb core and Kevlar Honeycomb core. To process honeycomb core, it is crucial to ensure the honeycomb core need to be dried first. The drying process was done in order to remove the moisture content in the honeycomb core. The drying is done by using drying oven with required temperature and duration. These projects focus to study the core that dried in drying oven at 120^{o}C for 2 hours minimum because it was used in current production. This project was conducted to investigate the characteristic of the honeycomb core. To prove what happen to honeycomb core that after been dry whether it expand or shrink at which area. For RD of 200mm, NRD 400mm and RD of 400mm, NRD 200mm, Nomex and Kevlar core shows no significant effect in terms of dimension when exposed to environment for 2 hours and 12 hours. For RD of 200mm, NRD 400mm and RD of 400mm, NRD 200mm, Nomex core shows same effect in terms of dimension which both RD and NRD shrink when drying for 2 hours and 12 hours. For RD of 200mm, NRD 400mm and RD of 400mm, NRD 200mm, Kevlar core shows same effect in terms of dimension which both RD shrink and NRD expand when drying for 2 hours and 12 hours.

ABSTRAK

Permintaan yang berterusan untuk struktur kurang-berat memastikan pembinaan sandwic 'honeycomb' mempunyai banyak kelebihan. Dalam industri pesawat, secara amnya 'honeycomb core' terbahagi kepada dua jenis iaitu 'Nomex Honeycomb core' dan 'Kevlar Honeycomb core'. Memproses 'honeycomb core' adalah penting untuk pastikan 'honeycomb core' perlu dikeringkan dahulu. Proses pengeringan perlu dilakukan untuk membuang kandungan kelembapan dalam 'honeycomb core'. Pengeringan dilakukan dengan menggunakan ketuhar pengeringan dengan suhu dan jangka masa yang ditetapkan. Projek ini dijalankan untuk mengkaji 'honeycomb core'yang dikeringkan dalam ketuhar 120^{o}C dimana ia perlu dikeringkan di dalam ketuhar pengeringan selama 2 jam minimum kerana ia digunakan dalam pengeluaran sekarang. Projek ini dilakukan untuk mengkaji sifat 'honeycomb core'. Untuk membuktikan apa yang berlaku kepada 'honeycomb core' selepas menjadi kering sama ada ia mengembang atau mengecut di kawasan mana. Untuk RD 200mm, 400mm NRD dan RD 400mm, 200mm NRD, 'Nomex' dan 'Kevlar Honeycomb core' tidak menunjukkan kesan yang ketara dari segi dimensi apabila terdedah kepada persekitaran untuk 2 jam dan 12 jam. Untuk RD 200mm, 400mm NRD dan RD 400mm, 200mm NRD, 'Nomex Honeycomb core' menunjukkan kesan yang sama dari segi dimensi di mana kedua-dua RD dan NRD mengecut apabila dikeringkan selama 2 jam dan 12 jam. Untuk RD 200mm, 400mm NRD dan RD 400mm, NRD 200mm, 'Kevlar Honeycomb core' menunjukkan kesan yang sama dari segi dimensi di mana RD mengecut dan NRD mengembang apabila dikeringkan selama 2 jam dan 12 jam.

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CHAPTER 1

INTRODUCTION

1.1 Background

The continuous demands for low-weight structures ensure that honeycomb sandwich construction have many advantages. This will give great advantages to the manufacturer of honeycomb sandwich construction. By taking this opportunity, the manufacturer can take further step by improving current process so that more benefit can be gain.

To produce honeycomb sandwich structure it requires fundamental components which are prepreg (Carbon Fiber Reinforced Plastic) and honeycomb core. This project discusses more about honeycomb core which is the main component that further reduces the already lightweight composite materials and increase stiffness of the structures. In aircraft industry, generally the honeycomb core can be divided into two types which are Nomex Honeycomb core and Kevlar Honeycomb core.

Nomex Honeycomb core solely made from polyamide paper while for Kevlar Honeycomb core, it made of N-636 polyamide paper (meta and para-aramid). Besides, honeycomb core can be distinguished by its cells size, thickness and density. Different cell size, thickness and density of honeycomb core will give different function. Honeycomb core are sourced from supplier of Hexcel, Euro Composites, Schuetz and McGill.The types of core that will be used in aircraft structure depending on customer requirement which already stated in their design.

1.2 Problem Statement

In honeycomb sandwich construction, both fundamental components which are prepreg and honeycomb core will be layup. Before layup process is done, prepreg and honeycomb core came from two sources whereby prepreg came from kitting room and honeycomb core came from honeycomb core processing room. The prepreg will be cut with special machine to specific dimension according to customer design and honeycomb core will be processed as customer design.

To process honeycomb core, it is crucial to ensure the honeycomb core need to be dry first. The drying process need to be done in order to remove the moisture content in the honeycomb core. The drying is done by using drying oven with required temperature and duration. Drying of honeycomb core usually depends on customer requirement. Examples are if drying honeycomb core in drying oven with 120^{o}C, it need to be dried in drying oven for 2 hours minimum. If drying honeycomb core in drying oven with 80^{o}C, it need to be dry in drying oven for 5 hours minimum and if drying honeycomb core in drying oven with 60^{o}C, it need to be dry in drying oven for 12 hours minimum.

This project focus to study the core that drying in drying oven with 120^{o}C which it need to be dry in drying oven for 2 hours minimum because it use in current production. In machining the core, the process of drying is done twice which before machining and before inspection. The simple process flow can be seen on figure 1.1 below.

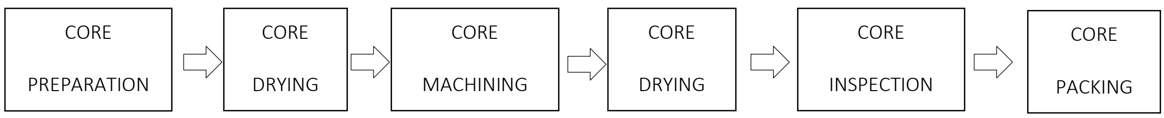

Figure 1.1: Core Process Flow

As stated above in figure 1.1, there are 6 processes to manufacture the core. This process applied for flat core only. To produce contour core, then it requires additional process which is forming process which will not be discuss in this project. The target is to reduce lead time from total cycle time for drying process. The detail cycle time of A320 Leading Edge Core process can be seen in figure 1.2 below.

	A320 LEADING EDGE	rev4 11/2013	
	Numbers of Panel per set	38	
	Minutes per panel	VA	NVA
1	Check paperwork	1.8	
2	Core template preparation	0.5	
3	Retrieve slice core from racking	4.5	
4	Dry slice core in drying oven/Update WO & form	3.0	120.0
5	Retrieve and attach tapes to CTT	3.0	
6	Retrieve core from drying oven/Update WO & form	3.0	
7	Cut core as per CTT	0.6	
8	Setup chamfer machine	1.5	
9	Chamfer core	4.5	
10	Clean up core/Burr	1.3	
11	Inspect core visually		5.0
12	Update paperwork and create tag for finish core	2.3	
13	Inspect core tagging/ID		5.0
14	Dry core in drying oven/Update WO & form	3.0	120.0
15	Retrieve core from drying oven/Update WO & form	2.3	
16	Inspect core		5.0
17	packing core/Close paperwork	2.0	
	Sub Total	33.3	255.0
	Total Hours (Total VA x Numbers of Panel per set) / 60min	21.1	

Figure 1.2: A320 Leading Edge Core process (Industrial Engineer of CTRM AC archive, 2014)

The data above was taken from Industrial Engineer of CTRM AC archive. The total time for drying process already use 240 minutes which equivalent to 4 hours in total. This is for ideal condition where it only dries for 2 hours minimum per process. By only reducing drying time 2 hours, then many outputs can be produced by production. The process of drying consider as non-value added (NVA). By reducing lead time, then it will reduce the cycle time of the work hence more output can be yield.

With current condition, the space in oven quite limited because now there are many project of core and the demand from customer has been increased. Instead of buying new oven which require a high amount of cost, this study is conducted as alternative so that oven space can be utilized efficiently. Besides, there will be quality issue where the cores have a risk to be torn off if the load in the oven too many due to high rate. This will cause many discrepancies to happen and additional works need to be done to rework the core and automatically will increase lead time.

Theoretically, as the honeycomb core being process over 45 minutes it needs to be dry again because within that time the honeycomb core that expose to environment tend to absorb moisture from surrounding will either expand or shrink. So, that is why the processing of honeycomb core need to be done in monitored area whereby the temperature and humidity of the room is controls. In a one time, the processes of producing A320 Leading Edge core are 19 cores and it not done separately for each panel. Therefore if the operator not carefully and ensure to complete all core within 45 minutes than the core have a risk of quality which the end of part (EOP) can be undersize.

1.3 Objectives of Study

The aim for this study is to eliminate drying process on machined the core. In order to achieve the aim, the objectives are as the following:

i. To investigate the effect of temperature and drying to the expansion of Nomex and Kevlar honeycomb core.
ii. To propose new template based on the expansion index for honeycomb core.
iii. To validate by run trial to prove it by machined the core without conditioning.

1.4 Scope of Study

This project will be conducted to investigate the characteristic of the honeycomb core. To prove what happen to honeycomb core that after being dry whether it expand or shrink at which area. As stated before, the honeycomb cores have two types that generally use in aircraft industry which are Nomex Honeycomb core and Kevlar Honeycomb core. Besides the honeycomb core can be distinguished by its cells size, thickness and density. Of course all this elements are the variables that need to be considering in this study.

This project intends honeycomb core to be dry just once which during inspection only in order to reduce frequency of dry the honeycomb core in the drying oven. Instead of drying core many times, the study intend for core to be dry once from whole process. The finished good honeycomb core still need to be dry before inspection is done so that it mimic the actual size as it require for core to be dry in next process (lay-up process). During layup process, the honeycomb core will be dry to remove moisture so that to avoid any trap air after the part was cured. This is important because if not this will cause delamination of the part which also cause life cycle of part will be shorter than normal.

As stated earlier, since this project focus only of drying temperature 120^{o}C at 2 hours minimum, then the result for temperature of 80^{o}C which need to be dry in drying oven for 5 hours minimum and drying honeycomb core in drying oven with 60^{o}C which need to be dry in drying oven for 12 hours minimum will produce different results. So, another study needs to be carried out.

Nomex Honeycomb core and Kevlar Honeycomb core are the material that use in this project. If other material of core such as Foam Honeycomb core and Aluminum Honeycomb core, then other study must be done because due to different type of material will produce different results.

Specific thickness, density and size will be used in this study. This will discuss detail in Chapter 3. Thickness, density and size other than stated will generate different results. Therefore other study must be conducted if want to know the results. It can be concluded that to use the different parameter than stated in this study will of course produce different result.

1.5 Significance of Study

This study which by eliminate 1 process from the total of 6 process will be beneficial to core operator. The cycle time of the work can be reduced hence more output can be yield. Beside improve output quantity and reduce cycle time, quality of the core produce can be secure by doing this study. This will make the efficiency of the process increase. Without these studies then there is risk which cannot meet customer demand and jeopardize the quality of core produced.

Other benefit of this study are power consumption (electric) of drying oven machine can be save and expedite the process of machining core which are cut the core as per Core Trim Template (CTT) and chamfering process. In other words, it will result the current cycle time to be reduced. Besides, the drying oven space can be utilized by other projects especially contour cores which use more space than flat core.

1.6 Research Planning

Research activities of this work is outlined in a Gantt chart (refer Appendix A).

CHAPTER 2

LITERATURE REVIEW

2.1 Honeycomb core

Airbus (2001) stated that the honeycomb is an anisotropic body of relatively low gross density of reinforced material, phenolic resin and node adhesive with directional physical and mechanical properties. The L-direction (L) is the longitudinal direction of the honeycomb parallel to the bonded areas and perpendicular to 'h'. L is also known as the ribbon direction. The W-direction (W) is the direction perpendicular to L and h. W is also known as the direction of expansion. The 'h' dimension or honeycomb sheet thickness is the cell height. According to the core type, the cell size shall be as follows:

i. Hexagonal = Diameter of the circle inscribed within the cell.
ii. Over-expanded = Distance between two parallel and opposite cell walls, measured in the expansion direction 'W' (providing near rectangular cell configuration).
iii. Flexible = Number of existing cells in 305mm, measured in the 'W' direction.

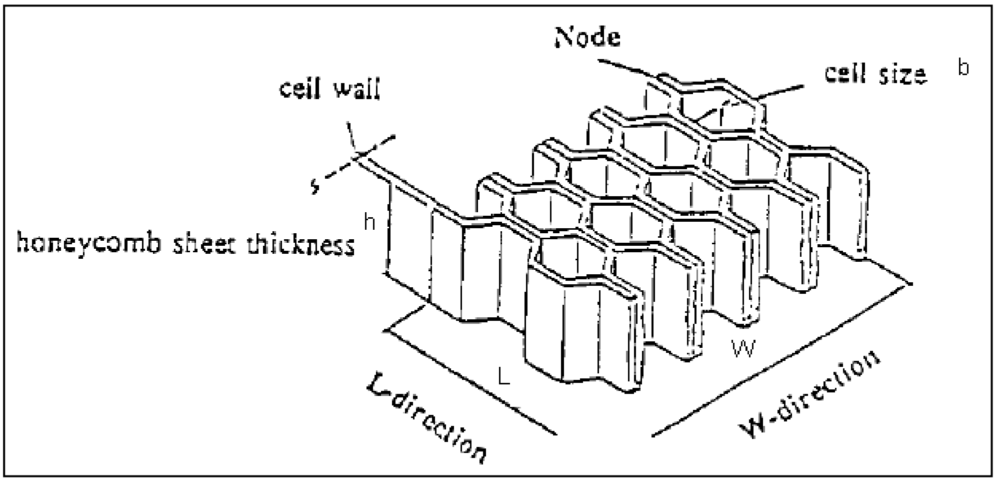

Figure 2.1: Honeycomb core hexagonal configurations (Airbus, 2001)

NetComposites (2014) stated that honeycomb cores are available in a variety of materials for sandwich structures. These range from paper and card for low strength and stiffness, low load applications (such as domestic internal doors) to high strength and stiffness, extremely lightweight components for aircraft structures. Honeycombs can be processed into both flat and curved composite structures, and can be made to conform to compound curves without excessive mechanical force or heating.

NetComposites (2014) claimed that thermoplastic honeycombs are usually produced by extrusion, followed by slicing to thickness. Other honeycombs (such as those made of paper and aluminium) are made by a multi-stage process. In these cases large thin sheets of the material (usually 1.2x2.4m) are printed with alternating, parallel, thin stripes of adhesive and the sheets are then stacked in a heated press while the adhesive cures. In the case of aluminium honeycomb the stack of sheets is then sliced through its thickness. The slices (known as 'block form') are later gently stretched and expanded to form the sheet of continuous hexagonal cell shapes.

NetComposites (2014) also claimed that in the case of paper honeycombs, the stack of bonded paper sheets is gently expanded to form a large block of honeycomb, several feet thick. Held in its expanded form, this fragile paper honeycomb block is then dipped in a tank of resin, drained and cured in an oven. Once this dipping resin has cured, the block has sufficient strength to be sliced into the final thicknesses required.In both cases, by varying the degree of pull in the expansion process, regular hexagon-shaped cells or over-expanded (elongated) cells can be produced, each with different mechanical and handling/drape properties. Due to this bonded method of construction, a honeycomb will have different mechanical properties in the 0° and 90° directions of the sheet.

NetComposites (2014) added properties of honeycomb materials depend on the size (and therefore frequency) of the cells and the thickness and strength of the web material. Sheets can range from typically 3-50 mm in thickness and panel dimensions are typically 1200 x 2400mm, although it is possible to produce sheets up to 3m x 3m. Honeycomb cores can give stiff and very light laminates but due to their very small bonding area they are almost exclusively used with high-performance resin systems such as epoxies so that the necessary adhesion to the laminate skins can be achieved.

2.2 Nomex honeycomb core

Digby (2006) stated that the honeycomb core shall be made from 100% synthetic wholly aromatic polyamide paper, consisting of short length fibres permanently bound together by fibrous binder particles, formed from the same synthetic polymer and containing no extraneous diluents in the web form. The honeycomb core is classified by density (kg/m3) and cell size (mm). This is the explanation of Nomex honeycomb core.

NetComposites (2014) stated that Nomex honeycomb is made from Nomex paper - a form of paper based on Kevlar, rather than cellulose fibres. The initial paper honeycomb is usually dipped in a phenolic resin to produce a honeycomb core with high strength and very good fire resistance. It is widely used for lightweight interior panels for aircraft in conjunction with phenolic resins in the skins. Special grades for use in fire retardant applications (eg public transport interiors) can also be made which have the honeycomb cells filled with phenolic foam for added bond area and insulation.

NetComposites (2014) claimed that Nomex honeycomb is becoming increasingly used in high-performance non-aerospace components due to its high mechanical properties, low density and good long-term stability. However, it is considerably more expensive than other core materials.

Based on information from Core Composites Inc. (2013), the standard for lightweight non-metallic composite construction is Nomex honeycomb. Made with aramid fiber paper (DUPONT Nomex or equivalent) coated with heat resistant phenolic resin is the commercial grade of honeycomb. In addition, it offers excellent resiliency, low density, lower pricing and high strength to weight ratio. Among advantages of Nomex honeycombs are:

- High Strength to Weight Ratio
- Corrosion Resistant
- Flame Retardant
- Good Thermal Insulation
- Formable

2.3 Kevlar honeycomb core

Airbus (2004) stated that honeycomb cores made of N-636 polyamide paper (meta and para-aramid) impregnated with phenolic resin in hexagonal configuration in a cured state for light-weight sandwich components. This is the explanation of Kevlar honeycomb core. The length of the honeycomb core will be known as L-direction. The width or expansion of the honeycomb core will be known as W-direction. The cell size and height will be representing by “b” and “h” respectively. The plain view of honeycomb core configuration can be defined as below.

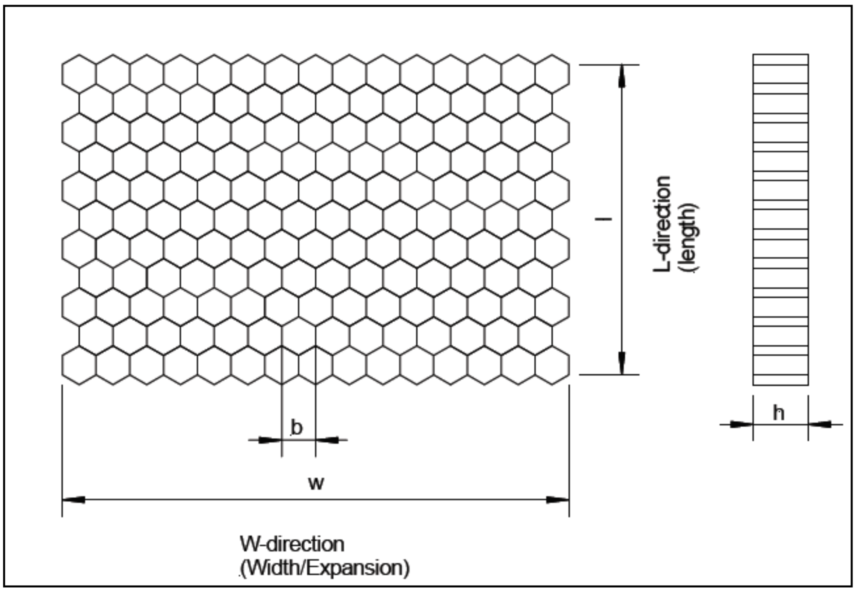

Figure 2.2: Honeycomb core hexagonal plain view configuration (Airbus, 2004)

Based on information from Core Composites Inc. (2014),Kevlar is the newest addition the honeycomb line. It is an extremely lightweight, high strength, non-metallic honeycomb manufactured with para-aramid fiber paper (DUPONT Kevlar® N636 or equivalent). The para-aramid paper is impregnated with a heat resistant phenolic resin. This core material exhibits improved performance characteristics over Nomex® and Korex® in the areas of weight, strengths, stiffness and fatigue. Among advantages of Kevlar Honeycomb are: